

# Opportunities for Precision Neutrino Physics and Constraining Oscillation Systematics with an LBNE Near Detector

The LBNE collaboration, January 31, 2013

The Long-Baseline Neutrino Experiment (LBNE) beamline [1] will provide a high-intensity broadband neutrino or anti-neutrino beam in the energy range 0.5-5 GeV. The facility is designed for initial operation at proton beam power of 700 kW ( $6.5 \times 10^{20}$  POT/yr), with the capability to support an upgrade to 2.3 MW. The primary proton beam energy is tunable in the range 60-120 GeV. In Phase 1 of the experiment the beam will be characterized by a beamline measurement system including tertiary muon measurement systems.

**Precision Neutrino Physics:** The core scientific capability of LBNE will be significantly enhanced by a highly capable neutrino detector to measure the unoscillated neutrino fluxes and their interactions at the near site. It would enable a very rich short-baseline physics program with more than a hundred unique physics and engineering PhD topics. Among the broad physics goals of this program [2] are to: (1) measure the absolute and relative flux of all four neutrino species,  $\nu_\mu$ ,  $\bar{\nu}_\mu$ ,  $\nu_e$  and  $\bar{\nu}_e$ , including the energy scales of neutrinos and antineutrinos, as required to normalize the oscillation signals at the Far Detector; (2) measure the cross section of neutrino- and antineutrino-induced inclusive and exclusive processes in nuclear targets across a large energy range (0.5–50 GeV) to 3% precision, to aid in the interpretation of the oscillation signals in the Far Detector; (3) measure the yield of particles produced in neutrino interactions such as neutral and charged pions/kaons, which are the dominant backgrounds to oscillation signals; and (4) measure precisely the fundamental electroweak and strong interaction parameters that are accessible to neutrino physics; and (5) perform sensitive searches for new physics, such as sterile neutrinos.

**Near Detectors:** Two options are being considered by the collaboration: a straw-tube Fine-Grained Tracker (FGT) [3, 4] with embedded high-pressure argon gas targets and a liquid argon TPC tracker (LArTPCT) [3]; both detector systems are located inside a large 0.4 T dipole magnet instrumented with scintillator planes for measuring outgoing muons. The Near Detector is designed to measure neutrino event rates and cross sections on argon for  $\nu_e$ ,  $\bar{\nu}_e$ ,  $\nu_\mu$  and  $\bar{\nu}_mu$  charged-current and neutral-current scattering events to characterize the neutrino beam. The main advantages of the FGT design are its excellent track position and angular resolution along with its ability, due the low density of the straw-tube tracker, to distinguish electrons from positrons on an event-by-event basis over the full relevant energy range. The main advantages of the LArTPCT are the use of the same target nucleus within similar technology in the near and far detectors. The collaboration is performing simulations and physics studies to determine the optimal design for the near detector.

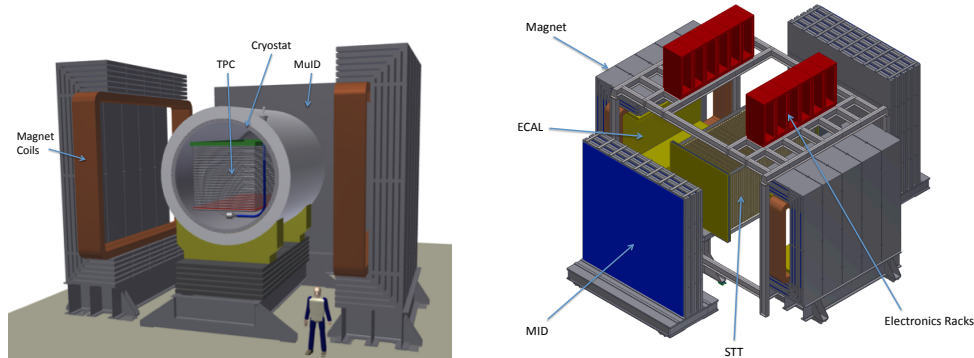


Figure 1: Left: Liquid Argon TPC Tracker; Right: Straw Tube Fine-Grained Tracker.

## References

- [1] “Long-Baseline Neutrino Experiment (LBNE) Project, Conceptual Design Report: Vol. 2: The Beam-line at the Near Site.” Available at <http://lbne2-docdb.fnal.gov/cgi-bin/ShowDocument?docid=4317&asof=2012-10-29>.
- [2] “Physics Research Goals of the LBNE Project,” [http://lbne2-docdb.fnal.gov/cgi-bin/RetrieveFile?docid=3056;filename=PhysicsGoals\\_V2.0\\_PartialSignatures.pdf;version=8](http://lbne2-docdb.fnal.gov/cgi-bin/RetrieveFile?docid=3056;filename=PhysicsGoals_V2.0_PartialSignatures.pdf;version=8); “The 2010 Interim Report of the Long-Baseline Neutrino Experiment Collaboration Physics Working Groups,” T. Akiri *et al.*, arXiv:hep-ex/1110.6249.
- [3] A description of the near detector options can be found in a a conceptual design report for the full scope LBNE, available at <http://lbne2-docdb.fnal.gov/cgi-bin/RetrieveFile?docid=4724;filename=CDR-NDC-volume-final-101912-reduced.pdf;version=12>.
- [4] S. R. Mishra, Prog. Part. Nucl. Phys. **64**, 202 (2010); S. Mishra *et al.*, arXiv:hep-ex/0812.4527, to be submitted to NIM.